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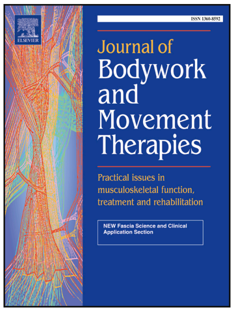

Quadriceps foam rolling and rolling massage increases hip flexion and extension passive range-of-motion.

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TITLE PAGE

Title:

Quadriceps foam rolling and rolling massage increases hip flexion and extension passive range-of-motion.

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ABSTRACT

Increases in joint range-of-motion may be beneficial for improving performance and reducing injury risk. This study investigated the effects of different self-massage volumes and modalities on passive hip range-of-motion. Twenty-five recreationally resistance-trained men performed four experimental protocols using a counterbalanced, randomized, and within-subjects design; foam rolling (FR) or roller massage (RM) for 60 or 120-second. Passive hip flexion and extension range-of-motion were measured in a counterbalanced and randomized order via manual goniometry before self-massage (baseline) and immediately, 10-, 20-, and 30-minute following each self-massage intervention. Following FR or RM of quadriceps, there was an increase in hip flexion range-of-motion at Post-0 (FR: Δ=19.28º; RM: Δ=14.96º), Post-10 (FR: Δ=13.03º; RM: Δ=10.40º), and Post-20 (FR: Δ= 6.00º; RM: Δ=4.64º) for all protocols, but not exceed the minimum detectable change at Post-10 for RM60 and RM120, and Post-20 for FR60, FR120, RM60, and RM120. Similarly, hip extension range-of-motion increase at Post-0 (FR: Δ=8.56º; RM: Δ=6.56º), Post-10 (FR: Δ=4.64º; RM: Δ=3.92º), and Post-20 (FR: Δ=2.80º; RM: Δ=1.92º), but not exceed the minimum detectable change at Post-10 for FR60, RM60, and RM120, and Post-20 for FR60, FR120, RM60, and RM120. In conclusion, both FR and RM increased hip range-of-motion but larger volumes (120- vs. 60-second) and FR produced the greatest increases. These findings have implications for self-massage prescription and implementation, in both rehabilitation and athletic populations.

Key words: flexibility, massage, self-massage, self-myofascial release, self-manual therapy.

TEXT

Introduction

Self-massage (SM) prior to exercise is becoming increasingly popular and may be performed by different tools (i.e. foam rolling (FR) and roller massage (RM)). The main effects are related to acute increases in passive range-of-motion (PROM) (Škarabot et al., 2015; Beardsley and Škarabot, 2015; Monteiro et al., 2017[a]). Although similar, FR and RM differ in the area of the underlying pressure; that is, FR covers a larger contact area and therefore allows a larger work in the target region. For example, Monteiro et al. (2017[a]; 2018) tested the effect of FR and RM in PROM and found that both tools increased PROM, but FR produced better effect than RM. This finding disagrees with conclusions of Grabow et al. (2018), who tested three different RM pressures (low, moderate, and higher) and did not found differences between them.

SM induced changes in PROM and may be influenced by both modality and volume. To the best of our knowledge, only Monteiro et al. (2017[a]; 2018) tested different modalities (FR and RM) on hip flexion and extension PROM and both studies found similar results with increases in hip PROM for FR and RM, but higher effects for FR. Additionally, only three pieces of papers have examined the effects of different SM volume on PROM (Bradbury-Squires et al., 2015; Couture et al., 2015; Monteiro et al., 2017[a]) and all researches found a dose-dependent response and indicate trends for better effects for 120-second. For example, Bradbury-Squires et al. (2015) performed 20- and 60-second of RM on the quadriceps and observed increases of 5 and 8 degrees, respectively. Monteiro et al. (2017[a]) performed 60- and 120-second of SM on the hamstrings and observed increases in both hip flexion, and extension PROM, immediately after intervention. In contrast, Couture et al. (2015) performed 20-second (two sets of 10-second) and 120-second (four sets of thirty-second) of hamstrings

FR and observed similar results (67.30˚ and 67.41˚, respectively) for knee extension ROM following each condition, but not statistically, possibly due to short duration of individual sets.

Many athletes and recreationally active individuals perform SM during a warm-up, between warm-up sets, or even between working sets, as it believed that greater PROM can be achieved which may enhance performance or reduce injury risk. Current highlighted findings suggest that effect of SM on PROM can be both local and global (Aboodarda et al., 2015; Kelly and Beardsley, 2016; Monteiro et al., 2017[bc]), which can allow for practitioners to improve their patients' PROM without endangering the potentially-sensitive tissue surrounding the muscle group of interest. Until now research on SM has primarily focused on immediate effects of SM, and there has been little research on the duration of these acute changes (Halperin et al., 2014; Škarabot et al., 2015; Monteiro et al., 2018). Therefore, the purpose of this study was to investigate the acute effects of different foam rolling and rolling massage volumes applied to the anterior thigh on hip flexion and extension PROM over time.

Methods

Participants

Twenty-five recreationally resistance-trained men (age: 26.2 ± 4.0 years; height: 176.7 ± 8.1 cm; weight: 65.0 ± 23.1 kg; body mass index: 27.1 ± 6.0), with no prior SM experience, and who were free of musculoskeletal injury or pain were recruited for this study based on *a priori* sample size calculation (Beck, 2013). Men were recruited both for convenience and the flexibility negative difference compared to women (Mier and Shapiro, 2013; Chino and Takahashi, 2018). An *a priori* sample size calculation (effect size =1.83; 1-β = 0.95; α = 0.05) using G*Power (Faul et al., 2007) found that 12 subjects would be sufficient to investigate the question posed; however, 25 participants were recruited. Subjects were instructed to refrain from participating in any lower body exercise or strenuous activity throughout the duration of the study. Anthropometric data were obtained using standard procedures: body mass (Techline BAL – 150 digital scale, São Paulo, Brazil) and height (Stadiometer ES 2030 Sanny, São Paulo, Brazil). Prior to the study all participants were provided verbal explanation of the study, and they read and signed an informed consent document after which they and completed a Physical Activity Readiness Questionnaire. The study was approved by the local ethics review board and all procedures were in accordance with the Declaration of Helsinki.

Experimental design

A single-blind, counterbalanced, randomized, within-subject design (Figure 1) similar to that of Monteiro et al. (2017[b]) was used. Subjects visited the laboratory on five occasions during a thirteen-day period with at least forty-eight hours between each session. The first visit was used to familiarize subjects with all procedures while experimental protocols were performed during the remaining four sessions. Following baseline measures, subjects completed the FR and RM conditions for 60 (FR60 and RM60) and 120 (FR120 and RM 120) seconds and retesting immediately (Post-0) following intervention. To assess the effects of SM on PROM over an extended period, hip extension and flexion were measured again at 10 (Post-10), 20 (Post-20), and 30 (Post-30) minutes post intervention. Subjects remained lying in rest between measures. These time points have been chosen to make the results more comparable to previous work (MacDonald et al., 2013; Halperin et al., 2014; Jay et al., 2014). Only the dominant leg was tested as referenced to the leg that they would kick a ball with (Škarabot et al., 2015).

[Insert Figure 1]

Self-massage protocol

The FR interventions utilized a foam roller with a hard inner core enclosed in a layer of ethylene vinyl acetate foam (Foam Roller Brazil, Porto Alegre, RS, Brazil), which has been shown to produce more pressure on the soft tissue than a conventional foam roller without a hard core (Curran, Fiore and Crisco, 2008). Foam rolling sessions were performed in a plank position with the upper thigh of the dominant leg on the foam roller. While keeping the knee of the dominant leg extended, participants were instructed to use their arms and non-dominant leg to propel themselves backward and forward on the foam roller between the acetabulum and quadriceps tendon in fluid, dynamic motions. Subjects were encouraged to support as much as possible of their entire bodyweight with the foam roller thus maximizing pressure on the limb. For a better representation of free-living training environments, subjects were free to choose the pace with which they performed the foam rolling. Participants were instructed to maintain pressure resulting in a self-rated score of 8 out of 10 on the pain level scale (Halperin et al., 2014).

The RM interventions were performed with a self-massage stick (Stick Trigger Point Technologies, Austin, Texas, USA). Subjects massaged themselves along the anterior aspect of the thigh while in a seated position with the dominant knee resting and extended. The RM was applied at different angles to target all areas of the anterior thigh. Subjects were instructed to roll between the acetabulum and quadriceps tendon in fluid dynamic motions. The application of RM pressure was controlled by a pain level scale in which a score of one represented no pain at all and a score of 10 represented maximal tolerable pain. Participants were instructed to maintain pressure resulting in a self-rated score self-rated score of 8 out of 10 on the pain level scale (Halperin et al., 2014).

Joint range of motion measurement

Passive hip flexion and extension PROM (Figure 2) of the contralateral leg were measured with a manual goniometer (Carci, São Paulo, BRA) using the standardized procedures outlined by Norkin and White (2009) and methodology described by Monteiro et al. (2018). Hip extension PROM (Figure 2A) and flexion (Figure 2B) was assessed in a prone position with the knees extended and in a supine position with the dominant knee flexed at 90 degrees and the opposite knee extended. The researcher then aligned the axis of the goniometer with the greater trochanter, and the arms of the goniometer with the lateral condyle of the femur and the mid-axillary line. When the trunk and thigh were parallel, hip flexion or extension PROM was defined as 0 degrees (positive PROM was defined by extension and flexion of the hip, respectively). During hip extension, was used a blood pressure calf as suggested by Moreside and McGill (2011). The blood pressure cuff was placed under the lumbar spine, and then inflated to 60 mmHg (Moreside and McGill, 2011). This pressure was monitored as the dominant leg was passively lowered to the end of the range of motion without associated changes in pelvic position or pressure in the blood pressure cuff (Moreside and McGill, 2011). Subjects had their hands across their chest throughout PROM testing. The same experimenter collected all PROM data and was always blinded as to which intervention the participants had completed.

[Insert Figure 2]

Statistical analyses

Data are presented as means ± standard deviations. Normality and sphericity were tested using a Shapiro-Wilks test and homoscedasticity was confirmed by a levene test. A repeated measures ANOVA (2×2 – volumes × conditions) was used to test for an interaction for Baseline 1, Baseline 2, and Baseline Higher. A degree of freedom of ANOVA values was reported between and within groups. Significant differences were identified using a

Bonferroni post-hoc test. Potential differences between baseline values were checked with paired T-tests. Eta-squared (eta²) was reported as a measure of effect size for significant main effects and main interactions within the ANOVA. Additionally, Cohen's *d* effect sizes were calculated using the formula $d = \frac{M_d}{s_d}$, where M_d is the mean difference and s_d is the standard deviation of differences. Cohen's d effect-sizes were defined as small (≥ 0.2), medium (≥ 0.5), and large (≥ 0.8) (Cohen, 1988). An alpha level of 0.05 was used. All analyses were performed using SPSS version 21 (SPSS Inc., Chicago, IL, USA).

To ensure that our measures were greater than measurement error, minimum detectable change (MDC) scores were calculated at the 95% level. To calculate MDC, standard error of measurement (SEM) was calculated first, using the formula $SEM = SD_{\text{test 1}}\sqrt{1-ICC}$, where SD_{test1} is the standard deviation of scores from the first test and ICC is the test-retest intraclass correlation coefficient. Then, MDC at the 95% level was calculated using the formula $MDC = 1.96(SEM)\sqrt{2}$.

Results

The minimum detectable change and effect size of PROMs for each condition and time point are presented in Table 1 and Table 2.

[Insert Table 1]

[Insert Table 2]

At baseline, there were no statistical differences ($p > 0.05$) between conditions for hip flexion or extension. Measurement reliability was determined by calculating an intraclass correlation coefficient for baseline hip flexion (FR60 = 0.811; FR120 = 0.839; RM60 =

0.634; RM120 = 0.725), which corresponds to a minimum detectable change of 7.82º, 7.28º, 11.49º, and 10.67º, respectively, and hip extension (FR60 = 0.683; FR120 = 0.762; RM60 = 0.607; RM120 = 0.690), which corresponds to a minimum detectable change of 3.66º, 4.56º, 4;56º, and 3.94º, respectively.

A significant difference was found by ANOVA for hip flexion in FR60 ($F_{(21,153)}$ = 46.608), FR120 ($F_{(23,151)}$ = 15.136), RM60 ($F_{(18,156)}$ = 29.900), and RM120 ($F_{(21,156)}$ = 21.152) with a volume × time interaction (FR60: $p < 0.001$, eta^2 = 0.191; FR120: $p < 0.001$, eta^2 = 0.257; RM60: $p < 0.001$, eta^2 = 0.098; RM120: $p < 0.001$, eta^2 = 0.116). Hip flexion PROM (Table 1; Figure 3) increased in Post-0 as compared to baselines values and remained increased for Post-20.

[Insert Figure 3]

A significant difference was found by ANOVA for hip extension in FR60 ($F_{(9,165)}$ = 33.300), FR120 ($F_{(10,164)}$ = 29.957), RM60 (F($_{6,166)}$ = 49.668), and RM120 ($F_{(8,166)}$ = 31.248) with volume x time interaction (FR60: $p < 0.001$, eta^2 = 0.039; FR120: $p < 0.001$, eta^2 = 0.184; RM60: $p < 0.001$, eta^2 = 0.123; RM120: $p < 0.001$, eta^2 = 0.124). Hip flexion PROM (Table 2; Figure 4) increased in Post-0 as compared to baselines values and remained increased for Post-20.

[Insert Figure 4]

FR produced greater increase in hip flexion PROM than RM in Post-0 ($p < 0.001$) and Post-10 ($p < 0.001$) (Table 1). FR induced in hip extension PROM were superior than RM in Post-0 ($p < 0.001$) and remained for Post-20 ($p < 0.001$) (Table 2). For both conditions, higher volume (120-second) produced greater changes in PROM.

Discussion

The purpose of this study was to investigate the acute effects of different foam rolling and rolling massage volumes applied to the anterior thigh on hip flexion and extension PROM over time. Despite the popularity of SM, to the best of our knowledge, this is only the third study (Monteiro et al., 2017[a]; 2018) that has directly compared the acute effects of FR and RM on hip PROM, and the first study that has performed this comparison for several different volumes (time of application; 60- vs 120-second). A major and novel finding of this investigation is that, although RM and FR appear as similar interventions they differ in the magnitude of their effect on PROM and that this magnitude is influenced by the volume of SM. The main effect confirms our initial hypothesis, which suggested different volumes (60- and 120-second) and SM tools (FR and RM) produce different changes in PROM; the greater PROM with FR is probably due to a higher-pressure area under target tissue during SM techniques. The current results for type of SM agree with previous research which has found that FR facilitates greater increases in PROM than RM (Monteiro et al., 2017[a]; 2018), and that these increases in PROM were present well after the intervention. Although not measured, the pressure between the modalities likely differed, as well as the contact area. In order to minimize these effects, subjects were instructed to maintain pressure resulting in a self-rated score self-rated score of 8 out of 10 on the pain level scale (Halperin et al., 2014).

Both modalities (FR and RM) resulted in increased PROM for 20-minute post SM intervention. Findings from previous research investigating the effect of SM volume on PROM are conflicting. The majority of studies have found increases in PROM immediately post SM interventions (Škarabot et al., 2015; Monteiro et al., 2017[a]), but not 30-minutes post intervention (Jay et al., 2014; Monteiro et al., 2018), while some studies have found no effect of volume on PROM (Bradbury-Squires et al., 2015; Couture et al., 2015; Vigotsky et al., 2015). For example, Škarabot et al. (2015) observed increases (9.1%) in ankle PROM after

90-second (3 sets of 30-second) of FR for the calf muscles when performed as a combination of FR and static stretching and the effect lasted less than 10-minute. Similarly, Monteiro et al. (2017[a]) found increases in hip flexion and extension PROM immediately after performed 60- and 120-second of hamstring SM for both tools and a better PROM response was found for FR in compare than RM and 120-second than 60-second. These results are consistent with those found in this study and all indicate that both modalities (FR and RM) increase the PROM for at least 20-minute post intervention. Additionally, the results confirm the trends indicated above (Bradbury-Squires et al., 2015; Couture et al., 2015; Monteiro et al., 2017[a]) and points to higher volumes (120- > 60-second) promoting better acute PROM responses.

Our results confirmed the initial hypothesis of this present study, which suggested that SM conditions increased global effects (Aboodarda et al., 2015; Kelly and Beardsley, 2016; Monteiro et al., 2017[d]; 2018). It is understood that this may be a global effect i.e. when one area of the body is treated, the effects are extending to neighboring regions by a central component response (Monteiro et al., 2017[bc]). This phenomenon has been shown previously. Aboodarda et al. (2015) found increases in pressure pain threshold on the calf (21% and 15.9%, respectively) at 30-second and 15-minute post-intervention after heavy rolling massage of the contralateral calf. Additionally, Kelly and Beardsley (2016) demonstrated a crossover effect, whereby FR the ipsilateral calf not only increased ipsilateral plantar flexion PROM, but also contralateral plantar flexion PROM after 3 sets of 30-second of plantar flexors foam rolling of the dominant leg. Furthermore, Monteiro et al. (2017[b]) performed 60- and 120-second with different self-massage tools on the hamstrings and observed increases in both hip flexion, and extension, immediately after intervention. Finally, Monteiro et al. (2017[d]) founded increases in overhead deep squat performance after perform FR in different area (lateral thigh, plantar surface of the foot, and lateral side of the trunk). The findings of this investigation and others (Aboodarda et al., 2015; Behm et al., 2016; Chaouachi et al., 2017; Kelly and Beardsley, 2016) show evidence that global changes do indeed occur, which can allow for practitioners to improve their patients' PROM without endangering the potentially-sensitive tissue surrounding the muscle of interest.

There is a possibility that improvements in PROM (similar found in the present study) have origin in a neurophysiological and/or mechanical response (Vigotsky and Bruhns, 2015). The first one, indicated that manual therapies promote analgesia and consequently increases in pain tolerance (Aboodarda, Spence and Button, 2015; Amann et al., 2009; Bazzichi et al., 2010; Drew et al., 2008; Vigotsky and Bruhns, 2015), and subsequently increases in PROM. This phenomenon is related to supraspinal mediators, such as central pain modulation, which have been professed to modulate pain perception (Aboodarda, Spence and Button, 2015; Behm et al., 2015; Vigotsky and Bruhns, 2015). To date, this is the main hypothesis related to the global effects of PROM. Although questionable, mechanical mechanisms are also plausible (Beardsley and Škarabot, 2015). From a mechanical stand point the increases in PROM could be due changes in fascia properties including fascial adhesions, myofascial trigger points, and viscoelastic properties of tissue and remodeling of collagen and elastin (Schleip, 2003[ab]; Adstrum et al., 2017; Stecco and Schleip, 2016). These changes may increase the tissue compliance and consequently PROM, but the mechanisms behind these are not fully understood as indicated by Eriksson Crommert et al. (2014) and Vigotsky et al. (2015), who founded show that the change in passive stiffness as a result of SM is unlikely to occur and/or last long enough. For example, Vigotsky et al. (2015) did not find changes in rectus femoris length in the modified Thomas test after a FR intervention. Furthemore, Eriksson Crommert et al. (2014), observed the effect of massage on the medial gastrocnemius stiffness with Shear Imaging Elastography, to determine how long changes PROM persist after massage. Authors found a significant decrease in PROM directly after massage (-5.2%) and no difference following 3-minute of rest (p = 0.83). These results indicate that muscle stiffness returned to baseline values in a short amount of time. Nevertheless, this type of study design has an important limitation when evaluating PROM since the authors performed testing bilaterally (one limb for massage condition and the other as a control).

There are a number of limitations/delimitations to bear in mind when interpreting the findings in this study. Firstly, the investigator was blinded as to which intervention was performed, but not blinded as to whether the participant performed an intervention, and this may have affected the answers found in subsequent protocols. Secondly, the SM pace was not controlled within or between individuals. This can be considered as both a limitation and a strength of this design. Specifically, the lack of control reduces the internal validity of the results, as the number/duration of each roll could possibly influence the outcome. Conversely, the freedom to choose the pace duration of each roll enhances the ecological validity of the findings, as it better represents real-life training scenarios. Thirdly, the pain level after foam rolling and roller massage were no controlled for. Foam rolling has probably led to increased pressure on the target area and therefore decrease in pain tolerance. This could trigger a protective cascade effect and lower ROM gains. Finally, our experimental design did not have a control group for comparisons.

In conclusion, SM (FR and RM) of the anterior thigh resulted in significant acute increases in hip flexion and extension ROM that lasted at least 20-minute post intervention; however, FR and higher volumes (120- vs. 60-second) induced the greatest increases in PROM. These findings may have direct implications for both clinicians and athletes as it indicates that when performing SM is used to increase hip PROM, FR should be utilized and performed for at least 120-second per muscle. Since the effect of SM appears to last for 20-

minute, SM performed immediately prior to competition, could be advantageous for athletes participating in events were increased PROM is required. This information may also be useful in developing proper SM prescription in both rehabilitative and athletic practice settings; since increased ROM might help improve training outcomes. Nonetheless, future studies should examine if different pressures applied during SM affects PROM and how additional modes of applying such pressure (i.e., tools) affects this outcome.

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TABLES

Table 1. Passive hip flexion range-of-motion minimum detectable change and effect size.

	FR60		FR120		RM60		RM120	
	MDC	*d*	MDC	*d*	MDC	*d*	MDC	*d*
Post-0	19.28º	3.01	17.24º	1.08	14.64º	2.34	14.96º	1.93
Post-10	13.04º	2.02	12.36º	0.75	8.32º	1.36	10.40º	1.33
Post-20	6.00º	0.95	5.16º	0.23	3.20º	0.58	4.64º	0.68
Post-30	-0.72º	-0.12	-0.36º	-0.02	-1.60º	0.29	-1.36º	-0.20

FR60 = foam rolling for 60-seconds; FR120 = foam rolling for 120-seconds; RM60 = rolling massage for 60-seconds; RM120 = rolling massage for 120-seconds; Post-0 = immediately after intervention; Post-10 = 10-minutes after intervention; Post-20 = 20-minutes after intervention; Post-30 = 30-minutes after intervention; MDC = minimum detectable change; *d* = Cohen's d effect size.

Table 2. Passive hip flexion range-of-motion minimum detectable change and effect size.

	FR60		FR120		RM60		RM120	
	MDC	*d*	MDC	*d*	MDC	*d*	MDC	*d*
Post-0	6.96º	2.58	8.56º	2.48	6.56º	3.48	6.32º	3.11
Post-10	3.60º	1.45	4.64º	1.48	3.04º	1.88	3.92º	1.57
Post-20	0.64º	0.29	2.80º	0.85	1.04º	0.65	1.92º	0.87
Post-30	-0.48º	-0.23	2.80º	0.39	0.40º	-0.24	0.24º	0.12

FR60 = foam rolling for 60-seconds; FR120 = foam rolling for 120-seconds; RM60 = rolling massage for 60-seconds; RM120 = rolling massage for 120-seconds; Post-0 = immediately after intervention; Post-10 = 10-minutes after intervention; Post-20 = 20-minutes after intervention; Post-30 = 30-minutes after intervention; MDC = minimum detectable change; *d* = Cohen's d effect size.

CAPTIONS TO FIGURES

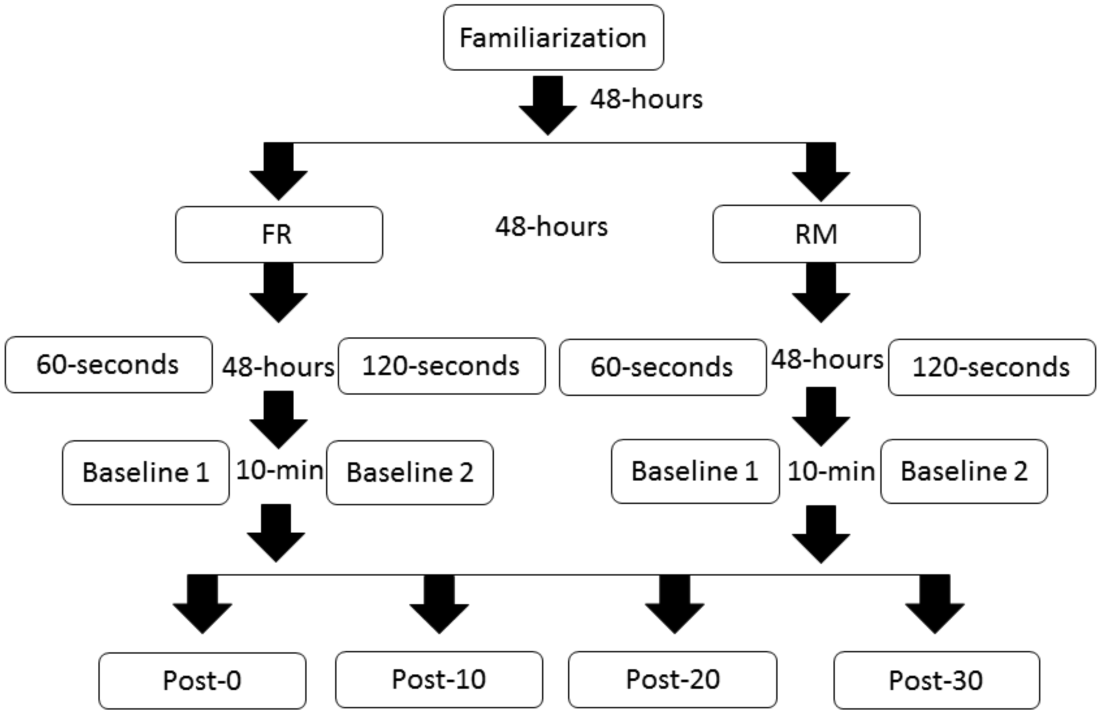
Figure 1. Study design. FR = foam rolling; RM = rolling massage; Post-0 = immediately after intervention; Post-10 = 10-minutes after intervention; Post-20 = 20-minutes after intervention; Post-30 = 30-minutes after intervention.

Figure 2. Passive hip range-of-motion. A = passive hip extension; B = passive hip flexion.

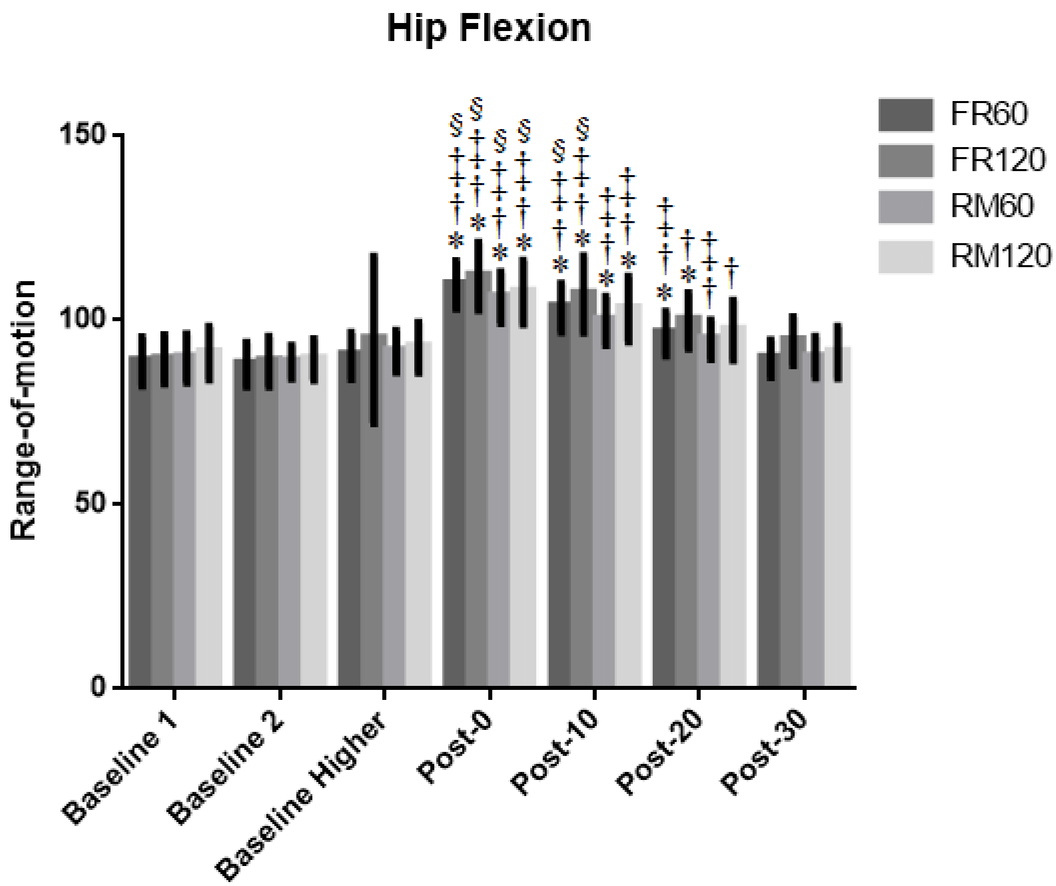
Figure 3. Passive hip flexion range-of-motion across each moments and conditions. FR = foam rolling; RM = rolling massage; Post-0 = immediately after intervention; Post-10 = 10-minutes after intervention; Post-20 = 20-minutes after intervention; Post-30 = 30-minutes after intervention. *Statistical difference for baseline 1; †Statistical difference for baseline 2; ‡Statistical difference for baseline higher. §Illustrates values that exceed Minimum Detectable Change.

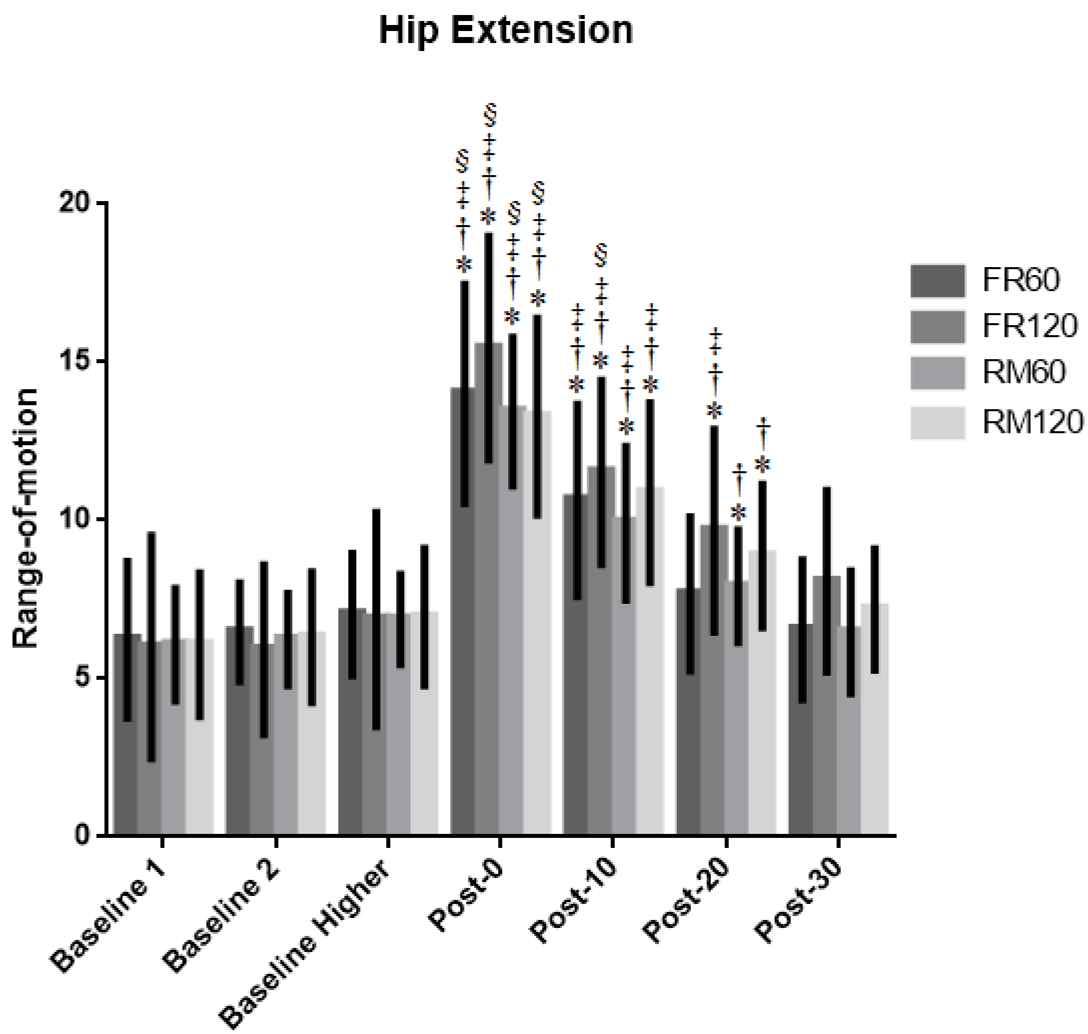
Figure 4. Passive hip extension range-of-motion across each moments and conditions. FR = foam rolling; RM = rolling massage; Post-0 = immediately after intervention; Post-10 = 10-minutes after intervention; Post-20 = 20-minutes after intervention; Post-30 = 30-minutes after intervention. *Statistical difference for baseline 1; †Statistical difference for baseline 2; ‡Statistical difference for baseline higher. §Illustrates values

that exceed Minimum Detectable Change.


Familiarization
48-hours
FR
48-hours
RM
60-seconds
48-hours
120-seconds
60-seconds
48-hours
120-seconds
Baseline 1
10-min
Baseline 2
Baseline 1
10-min
Baseline 2
Post-0
Post-10
Post-20
Post-30


A
B


Hip Flexion
FR60
FR120
RM60
RM120
Range-of-motion
150
100
50
0
Baseline 1
Baseline 2
Baseline Higher
Post-0
Post-10
Post-20
Post-30


Hip Extension
Range-of-motion
20
15
10
5
0
Baseline 1
Baseline 2
Baseline Higher
Post-0
Post-10
Post-20
Post-30
FR60
FR120
RM60
RM120